AN INQUIRY INTO THE RELATIVE MARKET PRICES OF ROUGHAGES AS COMPARED TO RELATIVE FEEDING VALUES

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INTRODUCTION

Feeds are divided into three general groups (1) roughages, (2) concentrates, and (3) roots. This study deals with the first of these groups. Roughages are divided into hays, silages, fodders, and straws. There are two hay sub-groups, legumes and non-legumes.

Roughages make up a large part of the ration of dairy cattle, beef cattle, and sheep in the United States. The relationships of the feeding value of the various roughages are vitally important to farmers in their feeding operations. These relationships will be referred to as "relative feeding values." Roughages are low in protein; however, they are a much cheaper source of total digestible nutrients in most sections of the United States than feeds that are high in protein.

Careful analysis is required to determine which of the available roughages is most economical at any time. It is not unusual to find one roughage overvalued in the market in relation to its feedings value to that of another roughage that can be substituted for it. For example, there may be a short crop of prairie hay in an area while there is a good crop of alfalfa. Some consistent users of prairie hay, such as the Kansas City stockyards, will continue to buy prairie hay rather than change to alfalfa or other substitute roughages because their customers expect prairie hay. Under this circumstance prairie hay may be overpriced relative to its feeding value when compared with alfalfa. This is a case of the demand being greater than supply

at prices which equate relative feeding values. The market price of various roughages is not always a useful guide to their comparative feeding values.

To maximize profit from feeding livestock a farmer must give careful attention to the prices of the different available feeds that can be substituted for each other. He should not get in the habit of feeding the same roughage regardless of price. Experiments have shown that the most economical ration for any class of livestock will vary from time to time as market prices change. For most classes of livestock there are several roughages that can be substituted, one for the other, without decreasing the efficiency of the ration. In other cases it may be necessary to change other parts of the ration when substituting one roughage for another to keep the ration well balanced and palatable. Otherwise, the loss in efficiency may more than offset the savings in price.

The purpose of this study is to analyze roughage prices and their ability to substitute one for the other in feeding livestock in order to provide a buying guide for roughage. There is presented herein: (1) methods of evaluating the relative feeding values of roughages; (2) an analysis of relative market prices of alfalfa and prairie hay; and (3) a comparison of market price relationships with relative feeding values.

REVIEW OF LITERATURE

Most of the information published in regard to the feeding value of the different roughages has been in the form of reporting

original experimental work in feeding standards. The most widely accepted source of feeding standards may be found in Morrison's, "Feeds and Feeding."[1] These feeding standards have been the outgrowth of the first feeding standards based on the digestible nutrients in feeds presented by Wolff, a German, in 1846. The Wolff standard was later revised by another German, Lehmann. These standards became known as the Wolff-Lehmann feeding standards and were widely used in Europe and America in computing balanced rations for livestock. Feeding standards based on net energy were presented in 1907 by Kellner in Germany and by Armsby in this country.[2]

In 1915, Morrison endeavored to combine in one set of standards what seemed to him to be the best guides available in the computation of rations for the various classes of livestock. These standards were first presented in the fifteenth edition of "Feeds and Feeding" published in 1915, and were called the "Modified Wolff-Lehmann Standards." They soon came to be known as the Morrison standards.[3] These standards have been revised and enlarged in later editions of "Feeds and Feeding."

Petersen of the Minnesota Agricultural Experiment Station devised an ingenious method that can be used to determine the relative feeding value of the various feeds.[4] He computed the

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[1] F. B. Morrison, Feeds and Feeding, 21st ed., p. 246.

[2] Ibid., p. 245.

[3] Ibid., p. 246.

[4] W. E. Petersen, A Formula for Evaluating Feeds on the Basis of Digestible Nutrients, Journal of Dairy Science, 15:293-297.

value of the various feeds by using "constants" based on a protein rich supplement and a carbohydrate rich supplement as a base. This method is discussed fully later in this paper.

R. D. Jennings[1] of the United States Department of Agriculture computed the relative value of common feed materials compared with corn when fed to different classes of livestock.

RELATIVE VALUES OF ROUGHAGES FOR LIVESTOCK AS INDICATED BY FEEDING EXPERIMENTS

Alfalfa

Alfalfa is undoubtedly the most outstanding roughage in the United States from the standpoint of the amount of high quality protein and total digestible nutrients that it furnishes. It is the highest in feed value of all commonly grown hay crops, is high in protein and minerals, and is an excellent source of vitamin A. Alfalfa is particularly outstanding having nearly three times the quantity of digestible protein found in timothy. Good alfalfa hay is the best roughage for dairy cattle, beef cattle, and sheep, and may be used as the standard of comparison.

Alfalfa hay may provide a large proportion of protein in the ration. However, this does not mean that it is necessarily the cheapest source of protein available. In some areas of the United States protein rich feeds are as cheap or cheaper per pound of protein than those feeds low in protein.

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[1] R. D. Jennings, Relation Between Feed, Livestock, and Food at the National Level, U. S. Dept. Agr. Cir. 836, p. 54.

Alfalfa Hay for Beef Cattle. Alfalfa hay is outstanding in value for use with the breeding herd. When any reasonable amount of good quality alfalfa hay is used in the beef cattle ration there will be no deficiency in the quality of protein, calcium or vitamins in the diet.

Fattening cattle fed alfalfa hay of good quality as the sole roughage usually do not need additional protein supplement in the ration to make economical gains. The breeding herd and calves being wintered on alfalfa as the only feed will maintain a thirfty growing condition.

Alfalfa hay may be used to supplement a low protein roughage such as sorghum silage in wintering young beef cattle or breeding cows. A rule of thumb is that three pounds of alfalfa will replace one pound of soybean meal or cottonseed meal. Fattening cattle, fed sorghum silage as the main roughage, will not eat enough alfalfa to properly balance the ration.

Alfalfa Hay for Sheep. Alfalfa is an excellent roughage for sheep as with other classes of livestock and can be taken as the standard for comparing other roughages. For sheep feeding, hay that is leafy and fine stemmed should be used, if possible, as it is of decidedly higher value than coarse stemmy hay.[1]

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[1] Morrison, op. cit., p. 349.

Red Clover

Red clover is second only to alfalfa as a roughage for nearly all classes of livestock. When cut at the usual stage of maturity, clover hay supplies about two-thirds as much digestible protein as alfalfa; however, it does supply a slightly higher amount of total digestible nutrients and slightly more net energy than alfalfa does.

Red Clover Hay for Dairy Cattle. Red clover is an excellent feed for dairy cattle but requires more protein supplement in the ration than alfalfa. The protein content is not as high as alfalfa.[1] Experiments have shown that clover is almost as valuable as alfalfa from the standpoint of the dairy cow. When alfalfa and clover are of comparable quality neither can be said to be greatly superior for milk production.[2] For dairy cattle alfalfa hay is superior to clover hay, largely because of its higher protein content.[3]

Red Clover Hay for Beef Cattle. Red clover is an excellent roughage for all types of beef cattle. In feeding trials it has proven equal or nearly equal to alfalfa. It has a lower protein content than alfalfa, but has a slightly higher net energy factor.

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[1] C. B. Bender, Feeding Dairy Cattle, N. J. Agr. Expt. Sta. Cir. 392, p. 18.

[2] C. C. Hayden, Clover vs. Alfalfa for Milk Production, Ohio Agr. Expt. Sta. Bul. 327, p. 18.

[3] Gleanings from Science, Wisconsin Agr. Expt. Sta. Bul. 388, p. 131.

Some early feeding trials at the Indiana Agricultural Experiment Station showed that the cattle made more rapid and more economical gains on clover hay than with alfalfa hay. This study indicated clover hay was worth 102 percent of alfalfa hay.[1]

After eight trials had been completed at Indiana with rations containing corn and cottonseed meal, results indicated that clover hay and alfalfa hay had the same feeding value. In these trials the quality of hay had more influence on its feeding value than the kind of legume from which it was made.[2]

Fuller and Morrison of the Wisconsin Station, averaging together the results of four trials, concluded that alfalfa hay was worth no more than clover hay for fattening cattle, even when advantage was taken of the higher protein content of the alfalfa hay.[3] In later work Fuller and Morrison stated that taking clover hay at the estimated farm price of $15.60 a ton, good alfalfa hay was worth $18.84 a ton or 20.7 percent more than clover hay. These trials showed that when only enough cottonseed meal or linseed meal is fed to balance each ration, good alfalfa is superior to clover hay.[4]

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[1] J. H. Skinner and F. G. King, Winter Steer Feeding, Indiana Agr. Expt. Sta. Bul. 183, p. 3.

[2] _____. Value of Alfalfa Hay for Fattening Cattle, Indiana Agr. Expt. Sta. Bul. 245, p. 6.

[3] Gleanings from Science, Wisconsin Agr. Expt. Sta. Bul. 388, p. 1313.

[4] New Pages in Farm Progress, Wisconsin Agr. Expt. Sta. Bul. 362, p. 92.

Red Clover Hay for Sheep. In feeding trials red clover has proven nearly equal to alfalfa in value for feeding sheep. Indiana experiments have shown conflicting results. In some trials the red clover hay was better than alfalfa hay. The data secured in an Indiana trial indicated the alfalfa hay at $18 a ton would be worth the same as clover hay at $20.10 a ton.[1] Another experiment at this station indicated that had clover hay and alfalfa hay been valued at the same price per ton there would still have been a difference in profit of 22 cents per lamb in favor of clover hay.[2]

A later trial did not agree with the previous trials on this subject. This later trial resulted in a cost of $7.87 per hundred pounds of gain with alfalfa hay and corn, as compared to $8.81 per hundred pounds with clover hay and corn in the ration.[3] The results of another experiment showed that in two lots clover hay produced better results and in two lots alfalfa hay produced the better results. In every case there was a difference in the relative quality of the two hays.[4]

> It would appear that when there is a difference in the feeding value of clover hay and alfalfa hay, it is the quality and not the variety of the hay that affects the results.[5]

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[1] J. H. Skinner, and F. G. King, Fattening Western Lambs, Ind. Agr. Expt. Sta. Bul. 179, p. 397.

[2] _____. Fattening Western Lambs, Ind. Agr. Expt. Sta. Bul. 184, p. 903.

[3] _____. Fattening Western Lambs, Ind. Agr. Expt. Sta. Bul. 192, p. 12.

[4] _____. Fattening Western Lambs, Ind. Agr. Expt. Sta. Bul. 202, p. 12.

[5] Ibid., p. 13.

In an Ohio experiment corn and clover hay produced 9.4 percent greater gain on a smaller amount of feed per 100 pounds gain than did corn and alfalfa hay.[1]

Soybean Hay

Soybeans are an important crop in the Corn Belt region that can be utilized either for seed or hay. Good soybean hay ranks close to alfalfa hay in feeding value. It is about as high in digestible protein as alfalfa with a slightly higher total digestible nutrient content. Soybean hay is very palatable and is an excellent substitute for alfalfa. Ten to 20 percent of soybean hay is not eaten by livestock because of the large coarse stems. Pound for pound of hay consumed, soybean hay is about equal to alfalfa. Soybean hay is probably not worth more than about 85 percent of alfalfa because of the large amount of the soybean hay that is refused.

Soybean Hay for Dairy Cattle. Experiments have varied greatly in the relative feeding values of soybean hay when compared with alfalfa hay. The experiments have indicated that soybean hay is worth from 75 percent to over 100 percent of alfalfa in feeding value.

Experiments have shown that soybean hay is equivalent to alfalfa of like quanlity on the basis of hay consumed; however,

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[1] B. E. Carmichael and J. W. Hammond, Rations for Fattening Range Lambs, Ohio Agr. Expt. Sta. Bul. 245, p. 696.

wastage was from 10 to 15 percent while the alfalfa was practically all consumed.[1] Other experiments have indicated that: soybean hay was 6 percent more valuable for milk and 7.8 percent for butterfat production than good quality alfalfa hay.[2] Good soybean hay is superior to alfalfa hay as a feed for milk and for maintenance of body weight for dairy cattle.[3] Soybean hay can equal alfalfa for milk production and butterfat.[4] Alfalfa is 12 percent more economical; this does not take into account the amount of refused hay.[5] Soybean hay was worth only three-fourths as much as alfalfa hay (refused 19.2 percent of the soybean hay) in this Wisconsin experiment.[6] On the basis of actual amounts consumed, the efficiency of soybean hay compares favorably with other legumes.[7] A fact to be remembered is that 15 to 20 percent of the soybean hay is refused on the average.

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[1] J. C. Hackleman, O. H. Sears, and W. L. Burlison, Soybean Production in Illinois, Illinois Agr. Expt. Sta. Bul. 310, p. 471.

[2] T. M. Olson, Soybeans for Dairy Cows, South Dakota Agr. Expt. Sta. Bul. 215, p. 15.

[3] E. L. Anthony and H. O. Henderson, Soybean vs Alfalfa Hay for Milk Production, W. Va. Agr. Expt. Sta. Bul. 181, p. 10.

[4] Report of the W. Va. Agr. Expt. Sta. for the Biennium ending June 30, 1930, W. Va. Agr. Expt. Sta. Bul. 244, p. 20.

[5] O. F. Hunziker and R. E. Caldwell, Test of Three Protein Concentrates and Two Leguminous Roughages in Milk Production, Ind. Agr. Expt. Sta. Bul. 203, p. 3.

[6] New Pages in Farm Progress, Alfalfa Hay for Fattening Cattle, Wis. Agr. Expt. Sta. Bul. 373, p. 92.

[7] H. P. Rusk, W. B. Nevens, W. G. Kammlade, J. L. Edmonds, C. W. Crawford, W. E. Carroll and H. J. Sloan, Utilizing the Soybean Crop in Livestock Feeding, Ill. Agr. Expt. Sta. Cir. 369, p. 21.

Soybean Hay for Beef Cattle. Soybean hay is an excellent hay for beef cattle with the exception that 10 to 20 percent of it is not eaten by the cattle. The portion of the soybean hay that is eaten by the cattle is nearly equal to alfalfa or red clover.

Bohstedt of the Ohio Agricultural Experiment Station conducted an experiment, comparing soybean hay with red clover hay when fed with shelled corn and corn silage to fattening steers. On the basis of this experiment the feeder could have afforded to pay only 74 percent as much for soybean as for clover hay. On this basis, with clover hay worth $15 a ton, soybean hay had a feeding value of $11.10 a ton.[1] The relative value depends upon the quality of the hays compared. Soybean hays differ markedly. Much depends on the variety used, stage of maturity, yield of seed and other important factors.[2]

Soybean Hay for Sheep. Soybean hay has been satisfactory for sheep but apparently has some limitations. It has been satisfactory when fed to fattening lambs. When pregnant or nursing ewes have been fed soybean roughage throughout the winter results have been poor in some instances. It would therefore seem wise to use soybean hay for ewes only in combination with other roughages such as corn silage.[3] Very satisfactory results

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[1] W. E. Hammond, J. M. Evvard, and C. C. Culbertson, Soybean and Alfalfa Hays for Wintering Pregnant Ewes, Iowa Agr. Expt. Sta. Bul. 282, p. 245.

[2] Ibid., p. 245.

[3] Morrison, op. cit., p. 369.

have been obtained with soybean hay. The chief difference between the alfalfa and soybean hay is the greater amount of refuse from the soybean hay.[1] Kammlade and Mackey state: "In these experiments with western lambs, with corn at 65 cents a bushel and alfalfa hay at $20 a ton, soybean hay had a value of approximately $17 a ton for fattening lambs."[2]

> In an Iowa experiment, soybean hay was equal in feeding value to more than an equal weight of a combination of alfalfa hay and shelled corn. Using the edible feed consumed per head as the basis of comparison, 100 pounds of soybean hay saved 102 pounds of alfalfa hay and 54 pounds of corn. On the other group, 100 pounds of soybean hay saved 108 pounds of alfalfa hay and 26 pounds of corn. When soybean hay replaced alfalfa entirely 100 pounds saved 107 pounds of alfalfa hay and 11 pounds of corn.[3]

Nearly 14 percent of the soybean hay was refused in this experiment that was not taken into account in the above comparison. When the relative value of clover and soybean hay was figured on the basis of the hay offered (20 percent refused), the soybean hay had a value somewhat greater than clover.[4]

Lespedeza Hay

Annual lespedeza has become the most widely grown legume in the South. Hay made from the annual lespedeza is palatable, finer stemmed than alfalfa, and not far from alfalfa in feeding

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[1] Rusk and others, op. cit., p. 24.
[2] Hackleman and others, op. cit., p. 471.
[3] Hammond and others, op. cit., p. 244.
[4] Ibid., p. 245.

value, although the protein content is somewhat less. Feeding trials indicate that annual lespedeza hay is nearly equal to alfalfa hay. Lespedeza hay when cut in bloom is excellent for all classes of stock, and hay of the best quality may equal or approach good alfalfa hay in feeding value. However, the relative value of lespedeza hay in comparison with alfalfa has varied considerably in experiment. In some trials it has been fully equal to alfalfa, but in most tests the value has been slightly lower, and in some instances lespedeza hay has been worth only about 80 percent as much as alfalfa hay.

Lespedeza Hay for Dairy Cattle. Experiments have shown that lespedeza hay was somewhat less palatable than alfalfa hay. The experiments have given conflicting relative feeding values. Some have indicated that lespedeza hay was nearly equal to alfalfa, and others have indicated that it was only worth 80 percent of alfalfa.

Wintering dairy heifers fed lespedeza hay gained 0.4 pounds as compared to 1.37 pounds for those fed alfalfa hay.[1] Alfalfa was 4.68 percent more efficient than lespedeza in North Carolina trials. In general, hay made from lespedeza is equal to hay from other legumes.[2] Lespedeza hay falls but little short of alfalfa in protein and is even superior in carbohydrate content.[3]

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[1] J. G. Archibald, J. Bart, M. L. Blaisdell, and A. F. Spelman, Quality In Roughages, Journal of Dairy Science 34:656, 1951.

[2] C. D. Grinnells, Lespedeza and Alfalfa Hay for Dairy Cattle, N. Car. Agr. Expt. Sta. Bul. 302, p. 4.

[3] Ibid., p. 18.

In the results from digestion trials and in actual milk production also, both Korean and Serica lespedeza were found to be almost equal in value. Lespedeza hay gave results equal to 80 percent of those from alfalfa hay.[1]

Lespedeza Hay for Beef Cattle. Lespedeza hay of good quality is an excellent hay for beef cattle. Lespedeza cut at the correct stage of maturity may equal alfalfa hay in feeding value.

Trowbridge, Comfort, and Hazen of the Missouri Station, in an experiment comparing alfalfa and lespedeza hays, concluded that steers fed alfalfa hay made slightly more economical gains than those fed lespedeza hay.[2] At the close of the tests the steers in all lots were classed as fleshy feeders and there was little difference in the degree of finish.

Grass Hay

Prairie hay resembles timothy hay in chemical composition and general value as a cattle feed. Prairie hays are composed of a large number of grasses and grasslike plants. If timothy and prairie hay are harvested at the early bloom stage or before they will make hay that compares favorably with average alfalfa in palatability and also in feeding value, except that prairie and timothy hay will have a lower protein and calcium content.

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[1] C. W. Holdaway, W. B. Ellett, J. F. Eheart, and A. D. Pratt, Korean Lespedeza and Lespedeza Serica Hays for Producing Milk, Va. Agr. Expt. Sta. Bul. 305, p. 7.

[2] E. A. Trowbridge, Comparative Feeding Values of Legume Hays for Wintering Native Calves, Mo. Agr. Expt. Sta. Bul. 387, p. 19.

Grass Hay for Dairy Cattle. Good timothy hay can be used satisfactorily for dairy cattle when legume hays are limited. The percent of protein in the supplement must be increased because of the low protein content of the timothy hay. Experiments have shown that legume hays and early cut timothy hay were approximately equal in value, but the late cut timothy proved much less palatable and resulted in lower milk production than any of the other hays. In feeding, the average intake of late cut timothy hay was only 35 to 40 percent as much as other hays and the actual milk production was approximately 25 percent lower.[1] Previous to 1932, where no mineral supplements were fed, the timothy hay ration produced 87.5 percent as much 4 percent milk as the alfalfa hay ration. Minerals were fed with timothy hay (1934-37 inclusive); the timothy hay ration produced 90.7 percent as much 4 percent milk as the alfalfa ration.[2] Alfalfa produced 17 percent more milk on the same ration when timothy was substituted for alfalfa.[3] Timothy is not as palatable and does not have the laxative effect of legumes; however, early cut timothy hay is very good cow hay.[4]

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[1] J. K. Loosli, V. N. Krukovsky, G. P. Lofgreen and R. B. Muskgrave, The Comparative Value of Timothy and Alfalfa Hays for Yield and Quality of Milk, Journal of Dairy Science 33:236.

[2] C. W. Holdaway, W. B. Ellett, J. F. Eheart and A. D. Pratt, Timothy Hay Compared with Alfalfa Hay as a Feed for Dairy Cows, Va. Agr. Expt. Sta. Bul. 65, p. 22.

[3] W. J. Fraser and C. C. Hayden, Alfalfa Hay vs Timothy Hay, Ill. Agr. Expt. Sta. Bul. 146, p. 18.

[4] C. B. Bender, Feeding Dairy Cattle, New Jersey Agr. Expt. Sta. Cir. 92, p. 18.

Prairie hay of high quality can be successfully used as the only roughage for dairy cattle, even for long periods if properly supplemented with concentrates containing adequate protein to balance the ration. Oklahoma reported in four feeding trials that prairie hay had a value of 85 to 90 percent that of alfalfa hay when supplemented with adequate protein.[1] Kuhlman of Oklahoma found that on the basis of the results obtained and using current feed prices, if alfalfa hay costs $15 a ton and cottonseed meal $48 a ton the prairie hay was worth 76 to 94 percent as much as alfalfa hay. On the average in four experiments prairie hay was worth 87 percent as much as alfalfa hay.[2]

Grass Hay for Beef Cattle. Timothy hay is low in protein and when it is used for beef cattle, one must feed large amounts of grain and also a higher percent of protein supplement to balance the ration. Timothy grown on well fertilized land is far superior to that grown on poor soils.

In some areas beef cattle often are wintered on prairie hay as the chief feed. If good quality prairie hay is fed it will usually furnish enough protein for yearlings or older beef cows. For young calves, a protein supplement should be furnished along with the prairie hay.

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[1] Science Serving Agriculture, Biennial Report July 1, 1941, to June 30, 1942, Okla. Agr. Expt. Sta., 1942.

[2] A. H. Kuhlman, Value of Prairie Hay for Milk Production, Journal of Dairy Science 26:736.

Baker at the Nebraska Agricultural Experiment Station compared silage and prairie hay in two trials for wintering steer calves. The calves fed prairie hay gained an average of 1.56 pounds, and the calves fed silage gained 1.84 pounds per head daily. As an average of the two trials, 1.0 tons of silage replaced 702 pounds of prairie hay, 12 pounds of soybean meal, and 55 pounds of grain.[1] Blizzard of Oklahoma, in feeding trials of wintering rations for steer calves being fed to gain 1.5 pounds per head per day, one ton of alfalfa hay replaced 1,652 pounds of prairie hay, 379 pounds of corn and 89 pounds of cottonseed meal (three year average).[2] Oklahoma tests indicate that when prairie hay sells for $11.50 per ton, alfalfa can sell for $18 and kafir silage for $7.60 and all will be equal from the cost standpoint in producing weight gains on steer calves fed a balanced ration with these roughages.[3]

Grass Hay for Sheep. Pure grass hay is less satisfactory for sheep than for beef cattle. Grass hay is lower in protein and calcium than the legumes hays. Prairie hay resembles timothy in chemical composition and general value as a feed for sheep. Prairie hay, when fed to pregnant ewes properly supplemented with

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[1] M. L. Baker, Wintering Steer Calves, Nebr. Agr. Expt. Sta. Bul. 350, p. 29.

[2] W. L. Blizzard, Beef Cattle Feeding Investigation, Okla. Agr. Expt. Sta. Bul. 237, p. 18.

[3] Science Serving Agriculture, Biennial Report 1936-1938-1939, p. 55.

cottonseed meal and finely ground limestone, gave results very similar to those obtained with alfalfa hay except during one year when prairie hay was quite unpalatable.[1]

Silages

Silage is a moist feed that has been preserved by fermentation in the absence of air. The principal crops that are used for silage are corn, sorghums, alfalfa and other legumes and grasses. Silage furnishes high quality succulent feed at any season of the year. It is highly palatable and livestock will usually eat more on a dry basis when it is included in the ration, than when receiving only dry feed.

The chemical composition and the nutritive value of silage vary according to the crop put in the silo, the stage of growth of the crop and other factors. The composition is similar to that of the green crop that was ensiled. There is little significant difference in the digestible nutrients of the dry matter of the crop, whether the crop is in the green state or made into silage, hay or fodder. Table 1 gives the composition and digestible nutrients of some of the more common forages both as dry roughages and as silage.

Silages vary tremendously in moisture content, and their value cannot be estimated without taking the moisture content

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[1] H. M. Briggs, The Use of Cottonseed Meal in the Ration of Pregnant Ewes, Journal of Animal Science 2:31.

Table 1. Chemical composition and digestible nutrients of certain forages.

Forage	Total Dry matter	Mineral matter	Crude protein	Fat	Crude fiber	N-free extract	Dig. protein	Total dig. nutrients
				(percent)				
Alfalfa in bloom green	26.3	2.2	4.4	0.7	8.4	10.6	3.4	15.6
Alfalfa silage wilted	36.0	3.2	6.0	1.4	11.7	13.7	4.1	21.3
Alfalfa hay	90.5	8.2	14.8	2.0	28.9	36.6	10.5	50.3
Corn fodder dent green	24.0	1.3	2.0	0.6	5.6	14.5	1.2	16.3
Corn silage	27.4	1.6	2.2	0.8	6.7	16.1	1.2	18.1
Corn fodder dry	82.6	5.2	6.8	2.1	21.8	46.7	3.3	53.9
Sorgo green	24.9	1.4	1.5	1.0	7.0	14.0	0.8	17.3
Sorgo silage	25.3	1.6	1.6	0.8	6.9	14.4	0.8	15.2
Sorgo fodder dry	88.8	7.1	6.2	2.4	25.0	48.1	3.3	52.4

Source: Compiled from data from Morrison's Feeds and Feeding, 21st edition, 1951.

into consideration. The quantity of nutrients depends upon the content of dry matter by weight. For example, 10 ton silage containing 25 percent dry matter may not be any more valuable than seven ton containing 35 percent dry matter.

Silage for Dairy Cattle. In early trials with dairy cattle some thought that silage in the dairy ration was desirable, because it added succulence to the ration. In Connecticut experiments the conclusion was reached that there is no need for succulence as such when the animals have water before them at all times.[1]

Experiments have shown that corn silage is an excellent feed for dairy cows. Corn silage has been proven to be worth approximately one-third as much as alfalfa hay. New Mexico experiments show that three tons of silage were required to replace one ton of alfalfa hay. Considering the hay at $10 per ton, little difference was indicated in the cost of the two rations, but the milk product of the alfalfa ration was 4 percent greater than that of silage.[2] Utah tests indicated that the addition of corn silage to a ration of alfalfa and corn, one ton of alfalfa hay was found to have a feeding value equal to from 2.5 to 3.0 tons of corn silage for milk production.[3]

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[1] Report of the Director for the year Ending June 30, 1933, Conn. (Storrs) Agr. Expt. Sta. Bul. 192, p. 12.

[2] L. Foster and J. R. Meeks, Dairy Cow Feeding Experiments, N. Mex. Agr. Expt. Sta. Bul. 122, p. 25.

[3] W. E. Carroll, Corn Silage in a Dairy Ration, Utah Agr. Expt. Sta. Bul. 190, p. 11.

In experiments with dairy cows good corn silage has actually been worth 33 to 40 percent as much as good legume hay.[1] In some experiments alfalfa silage has been equal in value per ton to well eared corn silage for milk production.[2]

Silage for Beef Cattle. Experiments have shown corn silage to be worth up to one-half as much as alfalfa hay. It is very difficult to place a relative value on corn silage because of its wide differences in grain and moisture content.

In an experiment with beef cattle, corn silage was supplemented with 1.56 pounds of pea meal per day; 100 pounds of alfalfa hay replaced 199 pounds of corn silage. Thus, if alfalfa hay is worth $25 per ton, one could afford to pay $9.78 per ton for corn silage.[3] This indicated that corn silage was worth 39 percent of alfalfa hay in this experiment.

In an early Iowa experiment the conclusion was that a ton of corn silage had a feeding value of approximately two-fifths to one-half that of a ton of alfalfa hay.[4]

A basal ration of corn silage and hay, properly balanced for protein, requires less grain for fattening cattle than does one of legume hay or molasses-legume silage. Differences in the amount of grain will depend upon the grain content of the corn

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[1] F. B. Morrison, Feeds and Feeding, p. 393.

[2] Ibid., p. 327.

[3] M. E. Ensminger, H. P. Singleton, W. W. Heinemann, T. J. Cunha and P. W. Colby, The Feeding Value of Roughages and Protein Supplements, Wash. Agr. Expt. Sta. Bul. 486, p. 25.

[4] J. M. Evvard, C. C. Culbertson, Q. W. Wallace and W. E. Hammond, Roughages for Fattening Two-Year Old Steers, Iowa Agr. Expt. Sta. Bul. 253, p. 388.

silage and also upon the proportion of grain to that of hay or silage in the ration. The less the amount of total grain fed, the greater will be the effect on the other feeds.[1]

In an Indiana trial in 1920 clover hay and corn silage was compared. One ton of corn silage replaced 613 pounds of clover hay in the feed required to produce a given amount of gain. On the basis of current prices at the time of the experiment, corn at 59 cents a bushel and clover hay at $13.27 a ton, corn silage was worth $6.83 a ton or 51 percent as much as the clover hay.[2] On the basis of the results obtained from this trial, one ton of corn silage replaced 4.61 bushels of corn and 613 pounds of clover hay in the feed required to produce a given amount of gain. With these results as the source of information, the following tabulation shows the value of corn silage per ton in a ration of shelled corn, cottonseed meal, clover hay, and corn silage.[3]

		Corn, price per bushel				
		$ 1.00	$ 1.25	$ 1.50	$ 1.75	$ 2.00
Clover hay	$10.00 Ton	7.67	8.82	9.96	11.12	12.27
" "	12.00 "	8.28	9.43	10.58	11.74	12.89
" "	14.00 "	8.90	10.05	11.20	12.35	13.50
" "	16.00 "	9.51	10.66	11.81	12.96	14.11
" "	18.00 "	10.12	11.27	12.42	13.04	14.73
" "	20.00 "	10.73	11.88	13.04	14.19	15.34
" "	25.00 "	12.26	13.41	14.58	15.73	16.87
" "	30.00 "	13.79	14.94	16.12	17.26	18.39

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[1] G. A. Branaman, and C. K. Davis, Legume Silage vs Corn Silage vs Legume Hay for Fattening Heifer Calves, Mich. Agr. Expt. Sta. Quarterly Bul. 24:16.

[2] J. H. Skinner and F. G. King, Corn Silage the Keystone of Economical Cattle Feeding, Ind. Agr. Expt. Sta. Bul. 235, p. 3.

[3] Ibid., p. 6.

Baker at the Nebraska Agricultural Experiment Station compared silage and prairie hay in two trials for wintering steer calves. The calves fed prairie hay gained an average of 1.56 pounds and the calves fed silage gained an average of 1.84 pounds per head daily. As an average of the two trials, 1.0 tons of silage replaced 702 pounds of prairie hay, 12 pounds of soybean meal, and 55 pounds of grain.[1] Oklahoma tests indicate that when prairie hay sells for $11.50 per ton, alfalfa can sell for $18 and kafir silage for $7.60 per ton and all will be equal from the cost standpoint in producing weight gains on steer calves fed a balanced ration with these roughages.[2]

In Michigan trials Atlas sorgo silage for fattening cattle was worth nearly 75 percent that of corn silage. With corn silage valued at $4 per ton the Atlas sorgo silage would have been worth $3.46 per ton or 86.5 percent that of corn silage. In a later trial with corn silage valued at $5 per ton, the price of Atlas sorgo silage would have been $2.78 per ton or 55.6 percent of corn silage. The average of the two trials would place a value on Atlas sorgo silage of 71.1 percent that of corn silage.[3]

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[1] M. L. Baker, Wintering Steer Calves, Nebr. Agr. Expt. Sta. Bul. 350, p. 29.

[2] Science Serving Agriculture, Report of Agr. Expt. Sta. Okla A & M College, 1936-1938, p. 44.

[3] F. G. King, Atlas Sorgo Silage for Fattening Cattle, Ind. Agr. Expt. Sta. Bul. 500, p. 5.

In Nebraska experiments calves fed prairie hay gained an average of 1.56 pounds and the calves fed sorghum silage 1.84 pounds per head daily. As an average of the two trials 1.0 ton of silage replaced 702 pounds of prairie hay, 12 pounds of soybean meal and 55 pounds of grain.[1]

FACTORS AFFECTING THE VALUE OF ROUGHAGES

Stage of Growth When Harvested

The stage of growth of a plant when harvested is one of the most important factors affecting the value of any hay. For dry roughages the more immature a forage is harvested the smaller the yield and the more nutritious the product. However, small yields and frequent cuttings increase the cost of the hay and if continued over a period of time it will be detrimental to the stand of the hay crop. The forage is usually harvested at an intermediate stage when neither the yield or quality of the hay is the highest. Taking into consideration the quality of hay, yield, composition, effect upon the stand and cost of harvesting, the best time to harvest the grasses, alfalfa, lespedeza, and clovers for hay is generally sometime between early and full bloom. Crops such as soybeans should be cut at a later stage. In most tests the largest yield of nutrients has been secured when the crop had not been cut before the seeds were well formed.

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[1] M. L. Baker, Wintering Steer Calves, Nebr. Agr. Expt. Sta. Bul 350, p. 29.

Palatability

In nearly all cases forages harvested in an immature stage are more palatable than those harvested at a later stage of growth. The young plants are tender, have a higher proportion of leaves, and the hay made from young plants is softer, all of which make for greater palatability.

The most important characteristic of the stage of growth is the change in composition as the plant matures. The protein and minerals are higher and the crude fiber is lower in young plants than in the more mature plants. These changes in composition are shown in Table 2 for alfalfa and in Table 3 for timothy.

Table 2. Effect of the time of cutting upon the chemical composition of alfalfa.

Stage of maturity	Protein	Fat	Fiber	N-free extract	Mineral matter
Alfalfa hay, all analyses	14.8	2.0	28.9	36.6	8.2
Alfalfa hay before bloom	19.0	2.7	22.6	36.7	9.5
Alfalfa hay 1/10 to 1/2 bloom	15.3	1.6	28.5	36.7	8.4
Alfalfa hay 3/4 to full bloom	14.1	1.9	30.2	36.2	8.1
Alfalfa hay past bloom	12.8	2.1	31.9	36.2	7.5

Source: Compiled from data taken from Morrison's Feeds and Feeding, 21st edition, 1951.

Table 3. Effect of the time of cutting upon the chemical composition of timothy.

Stage of maturity	Protein	Fat	Fiber	N-free extract	Mineral matter
Timothy hay, all analyses	6.5	2.4	30.2	45.0	4.9
Timothy hay before bloom	9.7	2.7	27.4	42.7	6.5
Timothy hay early bloom	7.5	2.4	30.0	44.4	4.7
Timothy hay full bloom	6.4	2.5	30.4	44.8	4.9
Timothy hay late bloom to early seed	6.1	2.7	29.7	45.5	5.0
Timothy hay late seed	5.3	2.3	31.0	45.9	4.5

Source: Compiled from data taken from Morrison's Feeds and Feeding, 21st edition, 1951.

Species of Plants

The species of plants used for forage are important from the standpoint of nutritive value. Roughages may be divided into classes, legume and non-legume roughages. Legumes have a relatively high protein and calcium content. They are also characterized by the fact that the leaves become detached very easily when dry. The non-legumes are low in protein and calcium content.

The stage of growth of the forage and the method of harvesting and curing have more effect on the feeding value of the hay than does the species or variety of the plant from which it is made. A good hay of any species is likely to be better than a poor quality hay from any other species that is commonly used for hay.

Skinner and King at the Indiana Station concluded after eight trials had been completed with rations containing corn and cottonseed meal, that clover hay and alfalfa hay have the same feeding value. In these trials the quality of hay had more influence on its feeding value than the kind of legume from which it was made.[1]

Moisture Content

The values of roughages are particularly affected by the percent of moisture they contain. Roughages such as corn and sorghum fodders and stovers vary widely in moisture content. For example:

> Analyses of corn fodder and corn stover show a water content ranging from over 50 percent in field cured material in wet seasons, down to 10 percent or less in arid regions or when cured under cover in a dry season. To show the difference in nutritive value of these extremes it may be stated that corn fodder or corn stover containing 10 percent water will carry 80 percent more nutrients per 100 pounds than a sample of the same forage containing 50 percent water.[2]

This would indicate that the dry corn fodder or stover would be worth 80 percent more than that containing 50 percent moisture. Moisture content would be a very important factor in determining the relative value of different roughages or the same roughage that might have different moisture contents.

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[1] J. H. Skinner and F. G. King, Value of Alfalfa Hay for Fattening Cattle, Ind. Agr. Expt. Sta. Bul. 245, p. 6.

[2] F. B. Morrison, Feeds and Feeding, p. 69.

Other Factors

The composition of roughages may be materially affected by other things such as the fertility of the soil on which the roughage was grown, by weathering and leaching during the curing process.

The value of the feed may be affected by the digestibility of the feed which is influenced by factors such as the amount of feed fed, the preparation of the feed, the proportion of protein in the ration and whether or not the ration being fed is balanced.

METHODS OF DETERMINING THE RELATIVE VALUES OF LIVESTOCK FEEDS

The best guide to relative feeding value of different roughages for any class of livestock is provided by actual feeding experiments with that class of livestock. There has been extensive work carried on to determine the value of the various roughages; however, there still is not enough data available to indicate the actual value of one roughage in relation to another. This is partly because of the extreme variabilities of roughages because of the stage of maturity at which cut, the curing and processing methods, storing methods, the fertility of the soil on which it was grown and moisture content. Morrison points out that there may be more actual difference in the feeding value of two lots of the same variety of hay than there is between hay of two entirely different kinds. For example, two loads of alfalfa

hay may differ more in value than a load of alfalfa hay and another of timothy hay.[1]

Total Digestible Nutrients

A method of comparing roughages is to compute the cost per pound of total digestible nutrients in each feed. It is the correct method of comparing the values of feed when protein rich feeds cost no more than those rich in other digestible nutrients (the abbreviation T.D.N. is often used) is the sum of all the digestible nutrients: protein, fiber, nitrogen free extract, and fat (the fat being multiplied by 2.25). The digestible protein is included because it will serve as a source of heat and energy when more is supplied than is required to meet the protein needs of the animals. This method will give the relative value of different feeds on the basis of total digestible nutrients.[2]

In most parts of the United States feeds that are high in protein generally cost more than those that are low in protein and rich in carbohydrates. When this is true it is necessary that a method be used to take into account both the total digestible nutrients and the digestible protein in the feed. Another method similar to this is to place a definite value on each pound of total digestible nutrients and an additional value on each pound of digestible protein. These values are determined

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[1] Ibid., p. 70.
[2] Ibid., p. 250.

from the market price of a protein rich feed as soybean oil meal, and a common grain such as corn. Tables can be worked out on this basis to show the relative values of roughages; however, the table can only be used as long as prices of the base feeds remain unchanged.

None of these methods take into account all of the factors that determine the value of any feed for a particular class of livestock. The only way that this can be done is through well planned experiments under practical conditions with that class of livestock.

Net Energy

Net energy values are probably more accurate than total digestible nutrients for comparing the value of roughages. There is a much greater loss of energy in the heat increment from each pound of digestible nutrients in the case of oat straw than with alfalfa hay.

> There is no question but what net energy values are theoretically more accurate measures than total digestible nutrients for productive purposes.
>
> Unfortunately, there are decided limitations in the use of net energy values for comparing the worth of various feeds for productive purposes. First of all, on account of the great cost of such investigation, and the amount of time required, the values of but very few feeds have been actually determined for the larger farm animals. The net energy values of other feeds must therefore be estimated from the content of digestible nutrients and other information. When this is done, it is often necessary to make arbitrary deductions, based on the judgment of the scientists, from the computed values, to produce a result that seems reasonable. Sometimes the computed values have not been corrected sufficiently on the basis of judgment, and

> figures have been published for certain feeds that are widely different from those that have been obtained in actual feeding experiments.[1]

The net energy values are different for the different classes of livestock. One roughage may have a much higher value for wintering beef cattle than for milk production. There are many other factors that are not considered in the net energy values as the temperature, kind of ration, amount of feed fed, and the variability of net energy factors.

The value of any roughage is relatively easy to compute using the net energy factor, see Table 4. The net energy factor is expressed as a percentage; therefore, to calculate the relative value of any roughage one needs only to multiply the net energy factor times the price of the base feed. For example, in Table 4, the net energy factor for red clover is 104.3 percent of alfalfa, and the price of alfalfa is $20; therefore, 104.3 times $20 gives the value of red clover relative to alfalfa.

The Petersen Method

W. E. Petersen of the University of Minnesota developed a method that can be used to evaluate the relative values of feeds even when the price of the base feeds change.

> When feeds are to be purchased, a method of evaluation, developed by the author, is available which will indicate the cheapest feed on the basis of its

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[1] Ibid., p. 53.

Table 4. The relative feeding value of roughages computed on the basis of Morrison's net energy factor.

Roughage	Net energy factor percent	Based on alfalfa as 100 percent	Relative value in dollars per ton if alfalfa is worth $20 per ton
Corn	100.0		
Alfalfa hay, all analyses	51.2	100.0	20.00
Clover hay, red, all analyses	53.4	104.3	20.86
Corn fodder, medium in water	45.1	88.1	17.62
Corn stover, medium in water	29.6	57.8	11.56
Kafir fodder, very dry including grain	48.9	95.5	19.10
Lespedeza hay, annual in bloom	48.7	95.1	19.02
Oat hay	48.4	94.5	18.90
Oat straw	29.1	56.8	11.36
Prairie hay, western, good quality	46.6	91.0	18.20
Soybean hay, good, all analyses	43.4	84.8	16.96
Timothy, all analyses	48.2	94.1	18.82
Wheat straw	12.5	24.4	4.88
Alfalfa silage, wilted before being ensiled	22.6	44.1	8.82
Atlas sorgo silage	18.2	35.5	7.10
Corn dent, well matured, all analyses	22.6	44.1	8.82

Source: computed from data from Morrison's Feeds and Feeding, 21st edition.

nutrient content. By multiplying the prices of cottonseed meal and corn by the constants set forth under these feeds and opposite the feed in question, and adding the two products, a figure is secured that gives the value of the feed. If the market price is higher than the indicated value, a cheaper substitute should be sought.

Example: If corn is worth $20 and cottonseed meal $30 per ton, what are oats worth?

The constant for corn is.....786 x 20 = $15.72
The constant for cottonseed meal is..109 x 30 = $ 3.72
Oats are worth per ton..... $18.99

The constants are arrived at from first determining the value of the feed in question from the price of cottonseed meal and corn. As a rule, the former is the cheapest source of protein and the latter the cheapest source of total digestible nutrients.

As 100 pounds of 43 percent protein cottonseed meal contains 37.6 pounds of protein and 42.6 pounds of total digestible nutrients, 57.24 pounds of corn (containing 42.6 pounds of total digestible nutrients and 4.1 pounds of digestible protein) can be subtracted therefrom, leaving 33.5 pounds of digestible protein. The difference in costs of 100 pounds of cottonseed meal and 57.24 pounds of corn should be charged to the 33.5 pounds of digestible protein to give a value for digestible protein.

The formula for determining the cost for a pound of protein:

$$\frac{\text{Cost of 100 pounds of cottonseed meal} - .5724 \text{ (cost of 100 lbs. corn)}}{33.5}$$

Example: Substituting with cottonseed meal at $50 per ton and corn at $25 per ton:

$$\frac{\$2.50 - (.5724 \times \$1.25)}{33.5} = 5.328 \text{ cents}$$

The value of a pound of nonprotein digestible nutrients may be arrived at by the following formula:

$$\frac{\text{Cost of 57.24 pounds corn} - (\text{value of protein} \times 4.1)}{42.6}$$

Substituting with corn at $1.25 per hundredweight and protein at 5.328 cents per pound:

$$\frac{1.25 \times 57.24 - (4.1 \times 5.328)}{42.6} = 1.167 \text{ cents}$$

> Applying the values obtained in this way to the digestible protein and nonprotein digestible nutrients of different feeds, their values may be determined.
>
> By considering the ratio of digestible protein to nonprotein digestible nutrients in relation to the ratio of these two nutrients for corn and cottonseed meal, the relative influence of the prices of corn and cottonseed meal upon the feed in question can be determined. This, together with corrections for the actual digestible protein and nonprotein digestible nutrients, enables the determination of constants for any feed to be applied to the prices of both cottonseed meal and corn for ascertaining the actual value.[1]

Morrison's Feed Evaluation Factors

Morrison used the average percentage of digestible protein and the estimated net energy values in computing his constants for feed evaluation.

> These constants have been computed with dent corn of Federal Grade No. 2 and soybean oil meal, expeller or hydraulic process, as the base or standard feeds. It is the belief of the author that net energy values provide a more accurate basis for feed evaulation than do total digestible nutrients. These constants have therefore been computed from the average percentages of digestible protein and the estimated net energy values which are given in the second and third columns of this same table.[2]

Table 5 shows the relative feeding value of the various roughages on the basis of Petersen's constants. Table 6 shows the relative feeding values of the various roughages on the basis of Morrison's constants.

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[1] W. E. Petersen, Dairy Science, 2nd edition, 1950, pp. 478-79.

[2] F. B. Morrison, Feeds and Feeding, p. 1133.

Table 5. The relative feeding value of roughages computed on the basis of Petersen's constants for evaluating feeds.

Roughage	Constant for cottonseed meal[1]	Constant for corn[2]	Cost per ton (dollars)	Relative feeding values based on alfalfa hay as 100 percent	Relative value in dollars per ton if alfalfa is worth $20 per ton
Alfalfa, medium	.215	.438	29.03	100.0	20.00
Clover, red	.109	.510	22.78	78.5	15.70
Corn fodder	-.023	.611	15.32	52.8	10.56
Corn stover	-.047	.489	10.02	34.5	6.90
Kafir fodder	.039	.390	1.396	48.1	9.62
Lespedeza	.217	.370	27.29	94.0	18.80
Oat hay	.023	.525	16.49	56.8	11.36
Oat straw	-.115	.663	9.59	33.0	6.60
Prairie hay	-.057	.644	13.56	46.7	9.34
Soybean hay	.127	.499	23.87	82.2	16.44
Timothy hay	-.053	.636	13.68	47.1	9.42
Wheat straw	-.098	.545	7.62	26.2	5.24
Alfalfa silages	.073	.173	10.53	36.3	7.26
Corn silage	-.011	.217	5.22	18.0	3.60

Source: Computed from data from Petersen's Dairy Science, 2nd edition, pp. 478-9, 1950.

[1] January 1, 1955, price of corn ($1.57 bushel) was used in computing values.

[2] January 1, 1955, price of cottonseed meal ($78 ton) was used in computing values.

Table 6. The relative feeding value of roughages computed on the basis of Morrison's feed evaluation factors.

Roughage	Constant for corn	Constant for soybean oil meal	Cost per ton (dollars)	Relative feeding values based on alfalfa hay as 100 percent	Relative value in dollars per ton if alfalfa is worth $20 per ton
Alfalfa hay, all analyses	.285	.232	26.18	100.0	20.00
Clover hay, red, all analyses	.421	.116	20.84	79.6	15.92
Corn fodder, medium in water	.440	.011	13.17	50.3	10.06
Corn stover, medium in water	.294	.002	8.39	32.0	6.40
Kafir fodder, very dry including grain	.449	.041	15.77	60.2	12.04
Lespedeza hay, annual in bloom	.382	.107	19.04	72.7	14.54
Oat hay	.430	.055	16.33	62.4	12.48
Oat straw	.330	-.040	6.12	23.4	4.68
Prairie hay, western, good quality	.495	-.031	11.84	45.2	9.04
Soybean hay, good, all analyses	.220	.219	23.24	88.7	17.74
Timothy, all analyses	.491	-.009	13.04	49.8	9.96
Wheat straw	.142	-.017	2.65	10.1	2.02
Alfalfa silage, wilted before being ensiled	.143	.085	10.63	40.6	8.12
Atlas sorgo silage	.173	.010	5.62	21.5	4.30
Corn silage, dent, well matured, all analyses	.235	-.010	5.80	22.2	4.44

Source: Computed from data from Morrison's Feeds and Feeding, 21st edition. January 1, 1955, prices of corn ($1.57 bushel) and soybean oil meal ($78 ton) were used in computing values.

To illustrate the use of these constants, let us take red clover hay. The constant for corn is .421 and the constant for soybean oil meal is .116. To find the value of the red clover hay multiply the price of corn by .421 the constant for corn; next multiply the price of soybean oil meal by .116 the constant for soybean oil meal; and then add the sums of the two. This shows a cost of $20.84 a ton for red clover hay with corn and soybean oil meal at the given prices. This figure was then converted into a percent of alfalfa. The last column shows the relative value based on alfalfa at $20 per ton.

RELATIVE FEEDING VALUES

Extensive experimentation work has shown that roughages can be substituted, one for the other, with good results if the ration is kept well balanced. The experimental work has provided a basis for estimating the relative feeding value of different roughages.

A common practice is to compare the feeding value of a pound of each of the roughages in terms of a pound of alfalfa, or a pound of corn. In other words, the feeding value of alfalfa or corn, whichever is used, equals 100.

Each roughage has a different value when fed to different kinds of livestock and in different rations. Many experiments have shown that red clover is worth as much as alfalfa when fed to beef cattle but only worth 90 percent of alfalfa for dairy cattle. The relative values of the different roughages are summarized in Table 7.

Table 7. Relative feeding value of a pound of roughage compared with alfalfa when fed to different kinds of livestock.

Roughage	Dairy cows	Fattening beef cattle	Wintering beef cattle	Fattening lambs
Alfalfa	100.0	100.0	100.0	100.0
Red clover	91.7	100.0	100.0	100.0
Lespedeza	91.7	100.0	---	---
Soybean	83.3	80.0	75.0	83.3
Timothy	66.7	---	75.0	50.0
Prairie	83.3	---	75.0	58.3
Oat	---	100.0	100.0	---
Corn fodder	66.7	100.0	100.0	108.3
Corn stover	25.0	20.0	83.3	---
Kafir fodder	66.7	80.0	83.3	83.3
Kafir stover	25.0	20.0	83.3	---
Oat straw	33.3	20.0	83.3	
Wheat straw	---	---	66.7	---
Corn silage with ears	33.3	60.0	41.7	50.0
Sorghum silage with heads	30.0	50.0	33.3	33.3
Hay crop silage	33.3	50.0	33.3	33.3

Source: Computed from data taken from R. D. Jennings, "Consumption of Feed by Livestock, 1909-47," USDA Circular 836, 1949, pp. 54-55.

The purpose of this table is to give data for converting different roughages into the feed equivalent of alfalfa. A pound of alfalfa is expressed as 100 percent and a pound of all other roughages as a percentage of alfalfa. Thus, in the data shown red clover is worth 91.7 percent of alfalfa or in other words, 100 pounds of average alfalfa is worth about 109 pounds of red clover hay. Some roughages are worth more for one class of livestock than for another as shown. The values given in Table 7, assume that the feed is to be fed as part of a properly balanced ration and that it is to be fed to the age of livestock which it is suited. The data in Table 7,

> . . . summarize the general relation in feeding value of corn and other feeds as determined by feeding experiments for the specific class of livestock fed fairly good rations. . . . when experimental evidence was not available, it was assumed, from the composition, that alfalfa was worth 60 percent as much as corn. Other roughages were compared with alfalfa as 100 percent as shown by experimental data. . . . figures for hay and other roughages are probably far better-than-average quality of roughage.[1]

There is not complete agreement as to the relative feeding values of roughages. This is largely because of the variability in roughages of the same species. Because of this great variability in roughages it is impossible to say that the relative value of one roughage is a certain percent of another in many cases.

The relative values of any two roughages may be expressed in the formula, $y = bx$, where y is one roughage, x the other

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[1] R. D. Jenning, Consumption of Feed by Livestock, 1909-47, USDA Circular 836, p. 55.

roughage and b the relative value. For example, when fattening beef cattle: (alfalfa hay price per ton) = (red clover hay price per ton) (1.0000) or when feeding dairy cows: (red clover hay price per ton) = (alfalfa hay price per ton) (.9170). The value of b can be found by using the data from Table 7. These values are given in Tables 8 through 11.

The relative feeding values for all possible price levels for any two roughages can be expressed graphically as in Fig. 1. The ratios expressed in Tables 8 through 11 indicate the slope of the line. By this device a comparison of the relative feeding values for any two roughages can be determined directly and the price area of economical substitution is pictured. To illustrate some market relationships, prices have been plotted. Notice the shift from 1951 to 1952 in the relative prices for alfalfa hay and timothy hay.

RELATIVE MARKET PRICES

This section is devoted to a presentation of analysis of price behavior. The primary concern here is with relative prices in order to analyze the possibility of a livestock producer reducing costs by substituting one roughage for another.

The mid-month price of alfalfa hay and prairie hay for Kansas was the basic data selected for analysis. This data was prepared by the Federal-State Crop Reporting Service.[1] The

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[1] Report of the Kansas State Board of Agriculture, Annual Summary Farm Facts, 1951,1952,1953, and 1954. Price Patterns,1950.

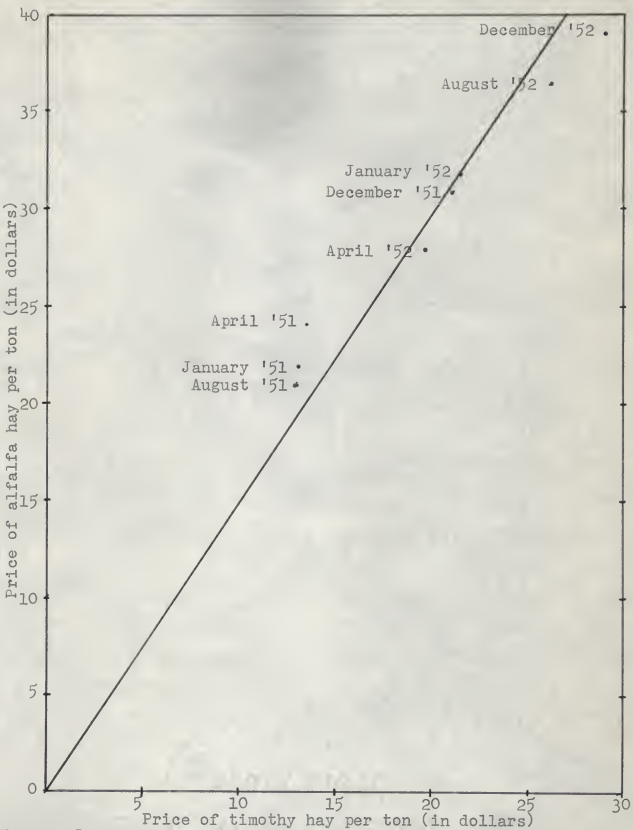

Fig. 1. Relative values of alfalfa hay and timothy hay when fed to dairy cows compared with actual market prices in a selected period.

Table 8. Relative feeding values for roughages when fed to dairy cattle.

Kind of roughage	Ratio I	Ratio II
Alfalfa vs red clover	A = 1.0905 RC	RC = .9170 A
Alfalfa vs lespedeza	A = 1.0905 L	L = .9170 A
Alfalfa vs soybean	A = 1.2005 S	S = .8330 A
Alfalfa vs timothy	A = 1.4993 T	T = .6670 A
Alfalfa vs prairie	A = 1.2005 P	P = .8330 A
Alfalfa vs Oat	---	---
Alfalfa vs corn fodder	A = 1.4993 CF	CF = .6670 A
Alfalfa vs corn stover	A = 4.0000 CS	CS = .2500 A
Alfalfa vs kafir fodder	A = 1.4993 KF	KF = .6670 A
Alfalfa vs kafir stover	A = 4.0000 KS	KS = .2500 A
Alfalfa vs oat straw	A = 3.0030 OS	OS = .3330 A
Alfalfa vs wheat straw	---	---
Alfalfa vs corn silage	A = 3.0030 CS	CS = .3330 A
Alfalfa vs sorghum silage	A = 3.3333 SS	SS = .3000 A
Alfalfa vs hay crop silage	A = 3.0030 CS	CS = .3330 A

Table 9. Relative feeding values for roughages when fed to fattening beef cattle.

Kind of roughage	Ratio I	Ratio II
Alfalfa vs red clover	A = 1.0000 RC	RC = 1.0000 A
Alfalfa vs lespedeza	A = 1.0000 L	L = 1.0000 A
Alfalfa vs soybean	A = 1.2500 S	S = .8000 A
Alfalfa vs timothy	---	---
Alfalfa vs prairie	---	---
Alfalfa vs oat	A = 1.0000 O	O = 1.0000 A
Alfalfa vs corn fodder	A = 1.0000 CF	CF = 1.0000 A
Alfalfa vs corn stover	A = 5.0000 CS	CS = .2000 A
Alfalfa vs kafir fodder	A = 1.2500 KF	KF = .8000 A
Alfalfa vs kafir stover	A = 5.0000 KS	KS = .2000 A
Alfalfa vs oat straw	A = 5.0000 OS	OS = .2000 A
Alfalfa vs wheat straw	---	---
Alfalfa vs corn silage	A = 1.6666 CS	CS = .6000 A
Alfalfa vs sorghum silage	A = 2.0000 SS	SS = .5000 A
Alfalfa vs hay crop silage	A = 2.0000 CS	CS = .5000 A

Table 10. Relative feeding values for roughages when fed to wintering beef cattle.

Kind of roughage	Ratio I	Ratio II
Alfalfa vs red clover	A = 1.0000 RC	RC = 1.0000 A
Alfalfa vs lespedeza	---	---
Alfalfa vs soybean	A = 1.333 S	S = .7500 A
Alfalfa vs timothy	A = 1.3333 T	T = .7500 A
Alfalfa vs prairie	A = 1.3333 P	P = .7500 A
Alfalfa vs Oat	A = 1.0000 O	O = 1.0000 A
Alfalfa vs corn fodder	A = 1.0000 CF	CF = 1.0000 A
Alfalfa vs corn stover	A = 1.2005 CS	CS = .8330 A
Alfalfa vs kafir fodder	A = 1.2005 KF	KF = .8330 A
Alfalfa vs kafir stover	A = 1.2005 KS	KS = .8330 A
Alfalfa vs oat straw	A = 1.2005 OS	OS = .8330 A
Alfalfa vs wheat straw	A = 1.4993 WS	WS = .6670 A
Alfalfa vs corn silage	A = 2.3981 CS	CS = .4170 A
Alfalfa vs sorghum silage	A = 3.0030 SS	SS = .3330 A
Alflafa vs hay crop silage	A = 3.0030 CS	CS = .3330 A

Table 11. Relative feeding values for roughages when fed to fattening lambs.

Kind of roughage	Ratio I	Ratio II
Alfalfa vs red clover	A = 1.0000 RC	RC = 1.0000 A
Alfalfa vs lespedeza	---	---
Alfalfa vs soybean	A = 1.2000 S	S = .8330 A
Alfalfa vs timothy	A = 2.0000 T	T = .5000 A
Alfalfa vs prairie	A = 1.7151 P	P = .5830 A
Alfalfa vs oat	---	---
Alfalfa vs corn fodder	A = .9236 CF	CF = 1.083 A
Alfalfa vs corn stover	----	---
Alfalfa vs kafir fodder	A = 1.2005 KF	KF = .8330 A
Alfalfa vs kafir stover	---	---
Alfalfa vs oat straw	---	---
Alfalfa vs wheat straw	---	---
Alfalfa vs corn silage	A = 2.0000 CS	CS = .5000 A
Alfalfa vs sorghum silage	A = 3.0030 SS	SS = .3330 A
Alfalfa vs hay crop silage	A = 3.0030 HS	HS = .3330 A

years 1915 to 1949 inclusive, were analyzed. The analysis was limited to alfalfa hay and prairie hay because price data were not available for other roughages.

Price ratios for alfalfa vs prairie hay were calculated. The results of the analysis for the 35 year period are presented in Table 12. Calculations were made for each five-year period (1915-19, 1920-24, etc.) to show how price relationships changed during the period.

Using the formula $y = bx$, one is able to measure dispersion of the mean ratio of market prices. The dispersion may also be indicated as has been done in Fig. 2. This shows the range that include 50, 68, 95, and 99 percent of the 420 price ratios. The relative feeding value of alfalfa and prairie hay when fed to wintering beef cattle and fattening lambs is indicated in Fig. 2.

Another test of the market price relationships is made in Fig. 3 by comparing the price spreads during the 35 year period. This is the results of the analysis of alfalfa hay and prairie hay.

An interesting factor to note is that if the data are plotted on a straight line it indicates that as the market price of prairie hay changes by $1 a ton, alfalfa will change $1.29 a ton in the same direction. It also shows that when the price of alfalfa is $11 a ton, prairie hay is about $7.50 a ton. When the market price of alfalfa is $11 a ton, the price of prairie hay will fall between $6.21 and $8.79 at least two-thirds of the time.

Table 12. Relatives of prices received by Kansas farmers for alfalfa hay-prairie hay, 1915-49, and by five-year intervals.[1]

Period	50% range		68% range		95% range		99% range		Mean ratio	Standard deviation
1915-19	1.175	1.301	1.145	1.331	1.056	1.420	1.000	1.476	1.238	.093
1920-24	1.362	1.510	1.326	1.546	1.220	1.652	1.154	1.718	1.436	.110
1925-29	1.539	1.837	1.467	1.909	1.255	2.121	1.122	2.254	1.688	.221
1930-34	1.706	1.916	1.655	1.967	1.505	2.117	1.412	2.210	1.811	.156
1935-39	1.638	2.100	1.527	2.211	1.199	2.539	.993	2.745	1.869	.342
1940-44	1.620	1.888	1.555	1.953	1.364	2.144	1.245	2.263	1.754	.199
1945-49	1.529	1.743	1.477	1.795	1.324	1.948	1.229	2.043	1.636	.159
1915-49	1.440	1.826	1.347	1.919	1.072	2.194	.901	2.365	1.633	.286

[1] In deriving this table the following data were used:

	Mean ratio	Standard deviation	
Alfalfa hay/prairie hay	1.633	2.86	50%(.6745s) 68%(1s) 95%(1.96s) 99%(2.56s)

To show the 50% confidence limits for ratios of alfalfa hay and prairie hay multiply the standard deviation by .6745 and then add and subtract this figure from 1.633. This same procedure is followed for the rest of the percentages by using (1s) for the 68% level, (1.96s) for the 95% level, and (2.56s) for the 99% level. The base line is the line passing through zero and the point (30, 18.50).

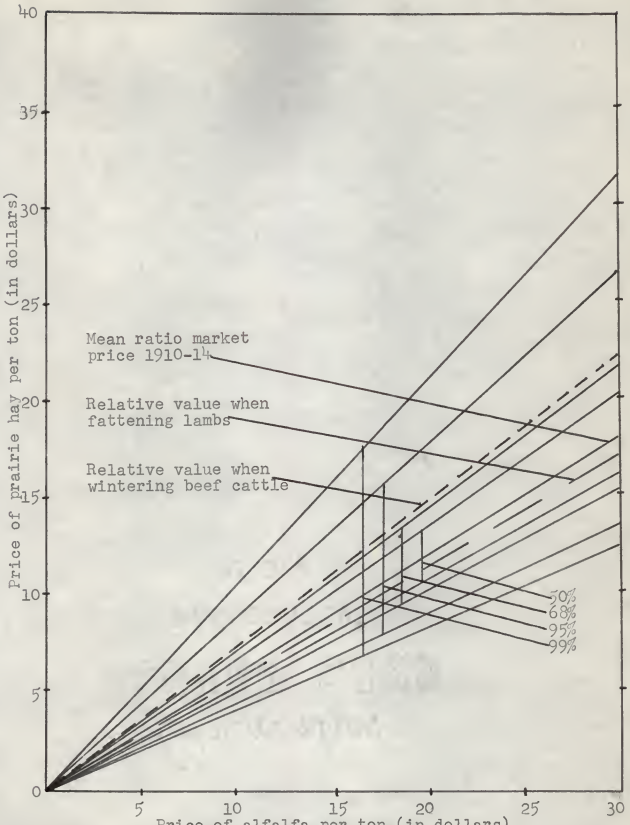

Fig. 2. Mean ratio of alfalfa and prairie hay prices, Kansas 1915-49.

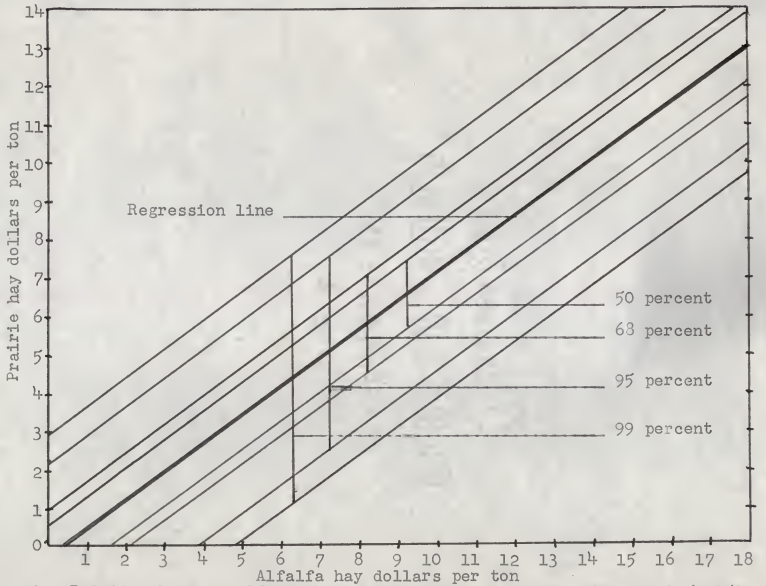

Fig. 3. Relation between alfalfa hay and prairie hay prices, Kansas 1915-1950.

Figure 4 shows the mid-month July average prices received by Kansas farmers for the years, 1934 to 1953. This indicates that at times the prices of prairie hay rise or fall a relatively larger percentage than does alfalfa hay.

MARKET PRICES VS RELATIVE FEEDING VALUES

Some comparisons have been shown that give an indication of the behavior of market prices in relation to feeding values of alfalfa hay and prairie hay.

There has been and continues to be a wide fluctuation in price ratios of alfalfa hay and prairie hay. Figure 5 shows the mean ratio for two five-year periods. This ratio line represents a 60-month period and many of the variations have been smoothed out. Note the difference in the mean ratios for the two periods. For example, when the price of alfalfa was $30 the price of prairie hay in 1920-24 was about $21 or about 70 percent of alfalfa, whereas, in the 1925-29 period prairie hay was about $18 or 60 percent of alfalfa.

SEASONAL VARIATION IN PRICES

> Seasonal variation is the month to month change in a time series due to the time of year. The principal factors causing seasonal change are relatively uniform and permanent; this movement may be considered entirely normal. Summer and winter, spring and autumn, the rainy season and the dry season, planting and reaping and their effect on customs and social activities result in about the same month to month change year after year.[1]

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[1] M. M. Blair, Elementary Statistics, p. 443.

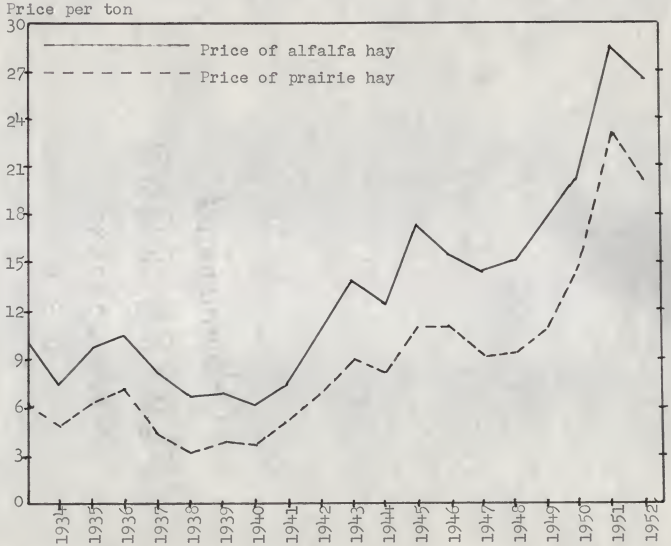

Fig. 4. Mid-month July average prices received by Kansas farmers, 1934-1953.

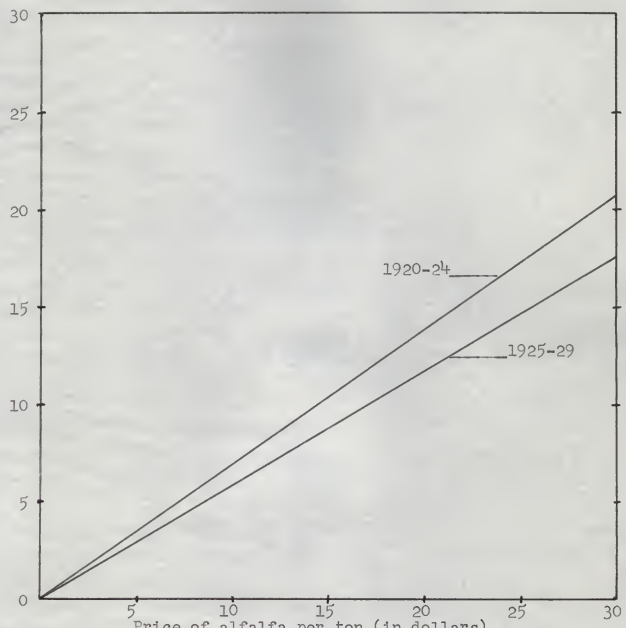

Fig. 5. Mean ratio of alfalfa hay and prairie hay prices, Kansas, 1920-24 and 1925-29.

Seasonal variation is easy to observe and measure. Seasonal price movements refer to ups and downs that regularly occur during certain seasons of the year.

The index of seasonal variation for alfalfa (Fig. 6) shows that there is a strong tendency for alfalfa prices to be the lowest in June and July with the highest prices in January. The actual value of the index for each month is shown by the heavy red line going up or down from month to month. This is called the seasonal trend line. The band on either side of this line indicated by black lines is called an "index of irregularity." This band indicates the extremes the seasonal trend line may be expected to stay within a majority of years. The width of this band gives some idea of the reliability that can be placed in a seasonal index. Other things being equal, the narrower the band the more reliable is the seasonal trend. For example, if the band is quite narrow, one can expect future prices to vary little in future years.

A seasonal index gives an indication of changes that can be expected during the year; a more direct application is made in estimating prices (for example) in some future month, with today's prices. The estimate is made by dividing today's price by the index for the current month and multiplying the results by the price index for the future month.[1]

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[1] P. L. Kelly, J. H. McCoy, and H. Tucker, Seasonal Variations in Prices, Sales, and Supplies of Milk and Feeds, Kansas Agr. Expt. Sta. Cir. 309, 1954, p. 5.

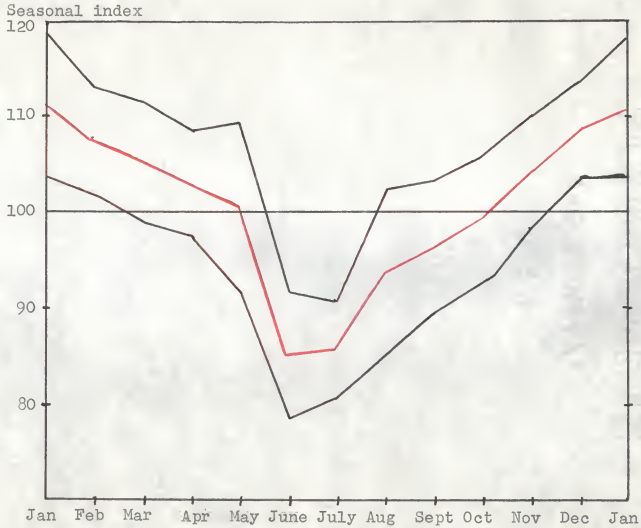

Fig. 6. Index of seasonal variation average Kansas price received by farmers for alfalfa hay per ton 1915-1954. (prices for loose hay 1915-1939 and baled hay 1939-1954)

$$\frac{\text{Present monthly price}}{\text{Present monthly index}} \times \text{Future monthly index} = \text{Estimated future monthly price}$$

For example, if the present price for alfalfa is $20 per ton and the current index is 90, then the estimated price six months from now (when seasonal index is 110) would be:

$$\frac{\$20}{90} = .2222 \times 110 = \$24.44$$

The index of irregularity can be used to compute an interval in which prices in the future months might be expected to fall in about 60 percent of such months.

The method of calculating this interval can be shown by using the alfalfa hay prices previously computed. For example, first multiply the estimated future price by the index of irregularity for that price series.

Alfalfa $24.44 x (.10) = $2.44

Now add the value obtained to the estimated future price to get the upper end of the interval. Subtract this same value to get the lower interval.

Alfalfa $24.44 + or - $2.44 = ($22 to $26.88)

> This method of forecasting, of course depends on the absence of disturbances that seriously alter the general price level, the supply, or the demand situation. It might lead to erroneous results in making estimates for a time when general business conditions are changing rapidly.[1]

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[1] Ibid., p. 6.

Seasonal Price Variation of Alfalfa Hay

Alfalfa hay prices were usually weak during June and July (Fig. 6). Hay feeding requirements are low at this time of the year, and new alfalfa is being cut. Price advanced consistently to early winter and remained near top levels during the winter months. This corresponds to the increasing seasonal need for hay or feed. Prices tended to decline slowly from January to May and June. After June they tended to work back up to a high in January.

Seasonal Price Variation of Prairie Hay

There is a strong tendency for prairie hay prices to be the lowest in July and the highest in January (Fig. 7). This is the same as for alfalfa hay, however, the seasonal variation is not as pronounced for prairie hay as for alfalfa hay. The index of irregularity for prairie hay is relatively small and can be considered reliable for use in forecasting future prices.

The index of seasonal variation shows the usual seasonal price pattern. However, each year differs from the average and farmers must take this into consideration. Averages hide certain relationships such as the movement of prices up or down from month to month. For example, how often have prices moved up from January to February and how often have they moved down?

Table 13 summarizes the number of times that prices have been higher than a given month. Here is how to use Table 13. For example, find the base month, February in the first column, then read to the right to the March column on the same line and

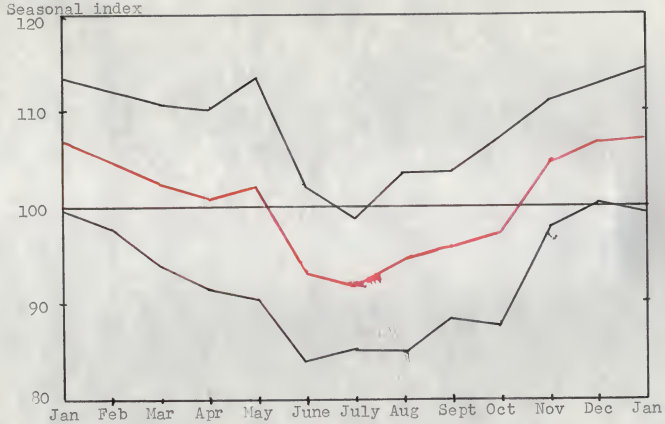

Fig. 7. Index of seasonal variation, average Kansas price received by farmers for prairie hay per ton 1915-1954. (price for loose hay 1915-1948 and baled hay 1948-1954)

Table 13. Alfalfa hay (baled), average prices received by farmers, Kansas, percent of times price went up from base month to subsequent month, 1939-1953.

Base Month	Subsequent Month																							
	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
January	33	20	20	13	7	7	20	27	33	47	60	71											
February		27	20	27	0	7	20	40	40	53	60	64	64										
March			27	27	0	13	20	40	40	60	60	71	64	64									
April				13	0	7	20	33	47	53	60	71	64	64	64								
May					7	13	20	40	53	67	73	79	64	64	64	71							
June						60	87	100	100	100	100	100	100	100	100	86	64						
July							80	93	100	100	100	100	100	100	100	7	57	50					
August								73	80	100	100	100	100	93	79	71	57	50	57				
September									87	100	100	100	86	93	71	57	29	36	50	50			
October										100	100	100	79	71	64	50	21	36	36	36	43		
November											73	93	64	57	50	36	7	21	29	36	36	50	
December												79	50	43	43	21	7	14	29	29	29	36	64

Table 14. Alfalfa hay (baled), average prices received by farmers, Kansas, percent of times price went down from base month to subsequent month, 1939-1953.

Base Month	Subsequent Month																							
	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
January	60	73	60	87	93	87	73	73	60	53	40	29											
February		53	73	73	100	87	73	60	53	47	40	29	29										
March			53	73	100	73	73	60	60	40	40	29	36	36									
April				80	100	80	73	60	53	47	40	29	36	36	36								
May					93	87	80	53	47	33	27	21	29	29	29	29							
June						27	7	0	0	0	0	0	0	0	0	14	29						
July							7	7	0	0	0	0	0	0	0	86	36	43					
August								13	7	0	0	0	0	7	21	29	43	50	43				
September									7	0	0	0	7	7	29	36	64	64	50	43			
October										0	0	0	14	21	29	43	79	64	64	64	50		
November											0	7	29	43	50	64	93	71	71	64	64	36	
December												14	43	50	57	79	93	86	71	71	71	57	36

Table 15. Alfalfa hay (baled), average prices received by farmers, Kansas, percent of times there was no change in price from base month to subsequent month, 1939-1953.

Base Month	Subsequent Month																							
	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
January	7	7	20	0	0	7	7	0	7	0	0	0												
February		20	7	0	0	7	7	0	7	0	0	7	7											
March			20	0	0	13	7	0	0	0	0	0	0	0										
April				7	0	13	7	7	0	0	0	0	0	0	0									
May					0	0	0	7	0	0	0	0	7	7	7	0								
June						13	7	0	0	0	0	0	0	0	0	0	7							
July							13	0	0	0	0	0	0	0	0	7	7	7						
August								13	13	0	0	0	0	0	0	0	0	0	0					
September									7	0	0	0	7	0	0	7	7	0	0	7				
October										0	0	0	7	7	7	7	0	0	0	0	7			
November											27	0	7	0	0	0	0	7	0	0	0	14		
December												7	7	7	0	0	0	0	0	0	0	7	0	

Table 16. Prairie hay (loose 1914-1949; baled 1949-1955), average prices received by farmers, Kansas, percent of times price went up from base month to subsequent month, 1914-1955.

Base Month	Subsequent Month																							
	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
January	25	28	28	35	23	28	25	33	38	45	50	45												
February		28	25	33	25	23	18	28	38	45	48	48	46											
March			33	43	23	28	25	35	43	48	55	55	54	54										
April				38	25	30	30	38	43	53	53	58	54	54	49									
May					15	20	25	39	46	44	51	49	50	50	48	48								
June						37	34	46	56	61	66	63	63	60	58	55	53							
July							41	59	59	68	71	68	63	65	53	53	50	49						
August								56	61	76	80	78	70	63	58	53	48	44	46					
September									59	71	80	78	68	58	55	58	45	44	41	46				
October										66	80	73	70	65	58	53	40	41	41	44	59			
November											66	68	55	48	45	38	33	31	28	38	46	51		
December												49	45	38	38	35	28	31	28	33	41	46	51	

Table 17. Prairie hay (loose 1914-1949; baled 1949-1955), average prices received by farmers, Kansas, percent of times price went down from base month to subsequent month, 1914-1955.

Base Month	Subsequent Month																							
	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
January	60	63	68	63	70	73	73	68	55	53	50	53											
February		63	73	63	70	78	80	73	60	53	50	48	54										
March			50	55	73	68	73	63	55	50	43	45	44	46									
April				43	73	68	70	60	50	48	45	40	41	46	49								
May					80	80	73	61	51	49	44	51	50	50	50	50							
June						56	63	46	41	37	29	34	38	38	40	43	48						
July							44	39	39	24	29	32	30	33	38	45	50	46					
August								39	29	22	20	17	25	38	43	43	50	54	54				
September									32	24	17	17	30	35	43	40	53	56	56	54			
October										17	10	15	25	30	35	38	53	59	56	51	36		
November											24	20	43	53	53	53	65	69	72	62	51	46	
December												34	50	50	60	60	70	69	72	67	59	51	49

Table 18. Prairie hay (loose 1914-1949; baled 1949-1955), average prices received by farmers, Kansas, percent of times price was same from base month to subsequent month, 1914-1955.

Base Month	Subsequent Month																							
	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
January	15	10	5	3	8	0	3	0	8	3	0	3												
February		10	3	5	5	0	3	0	3	3	3	5	0											
March			18	3	5	5	3	3	3	3	3	0	3	0										
April				20	3	3	0	3	3	0	3	3	5	0	3									
May					5	0	2	0	2	7	5	0	0	0	3	3								
June						7	2	7	2	2	5	2	0	3	3	3	0							
July							15	2	2	7	0	0	8	3	10	3	0	5						
August								5	10	2	0	5	5	0	0	5	3	3	0					
September									10	5	2	5	3	8	3	3	3	0	3	0				
October										17	10	12	5	5	8	10	8	0	3	5	5			
November											10	12	3	0	3	10	3	0	0	0	3	3		
December												17	5	13	3	5	3	0	0	0	0	3	0	

find 27. This means that the March prices have averaged above January prices 27 percent of the time during the past 15 years. Reading right on the same line one finds a 20 for April, 27 for May and zero for the month of June. This zero means that prices have never averaged above February for these months.

If the prices for the month of June do not go up then they must stay the same or go down. These price changes are recorded in Tables 14 and 15. March prices averaged the same as February 20 percent of the time, went up 27 percent of the time and went down 53 percent of the time.

Tables 16 to 18 record the month to month price changes for prairie hay.

SUMMARY AND CONCLUSIONS

Roughages make up a large part of the ration of dairy cattle, beef cattle, and sheep in the United States. The relationships of the relative feeding value of the various roughages are very important to the farmer in his feeding operations from an economic viewpoint.

Careful analysis is required to determine which of the available roughages is most economical at any time.

The best guide to the relative feeding value of the various roughages is provided by actual feeding experiments. There has been extensive work done along this line; however, there is still not enough data available to indicate the actual feeding value of one roughage in relation to another.

There are several methods of comparing roughages besides actual feeding experiments, such as computing the cost per pound of total digestible nutrients in each feed, net energy value determined by digestion trials, Petersen's method based on constants, and Morrison's feed evaluation factors.

These methods are all useful but all have limitations.

A common practice is to compare the feeding value of a pound of each of the roughages in terms of a pound of alfalfa or a pound of corn. In other words, the feeding value of alfalfa or corn, whichever is used, equals 100.

Table 7 has been compiled to show the relative values of the different roughages. The purpose of this table is to give data for converting different roughages into the feed equivalent of alfalfa. There is not complete agreement as to the relative feeding values of roughages.

The relative feeding values for all possible price levels for any two roughages can be expressed graphically as in Fig. 1. With this device, a comparison of the relative feeding values for any two roughages can be determined directly and the price area of economical substitution is pictured.

Price analysis of roughages has been necessarily limited to alfalfa and prairie hay because of a lack of price data on the other roughages. Price ratios for alfalfa vs prairie hay were calculated. Calculations were made for each five-year period to show how price relationships changed during the years.

There has and continues to be a wide fluctuation in price ratios of alfalfa hay and prairie hay. It is not unusual to find one roughage overvalued in the market in relation to its feeding value to that of another roughage that can be substituted for it. Some of the contributing factors causing this situation are as follows: (1) feeder's habit of feeding one kind of roughage regardless of cost, (2) imperfect knowledge of the prevailing market prices of the different roughages, (3) unacquainted with the possibilities of economical substitution, (4) demand and supply situation, and (5) roughages are so variable in quality that it is very difficult if not impossible to determine their actual feeding value in relation to another roughage.

Analysis of the seasonal price pattern of alfalfa and prairie hay indicates that alfalfa hay prices tend to be high in January and low in June with a small index of irregularity. Prairie hay prices tend to be high in January and low in July with a small index of irregularity.

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AN INQUIRY INTO THE RELATIVE MARKET PRICES OF ROUGHAGES AS COMPARED TO RELATIVE FEEDING VALUES

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Roughages make up a large part of the ration of dairy cattle, beef cattle, and sheep in the United States. The relationships of the feeding value of the various roughages are vitally important to farmers in their feeding operations. These relationships will be referred to as "relative feeding values."

A careful analysis is required to determine which of the available roughages is most economical at any time. It is not unusual to find one roughage overvalued in the market in relation to its feeding value to that of another roughage that can be substituted for it.

To maximize profit from feeding livestock a farmer must give careful attention to the prices of the different available feeds that can be substituted for each other.

The purpose of this study is to analyze roughage prices and their ability to substitute one for the other in feeding livestock. There is presented herein: (1) methods of evaluating the relative feeding values of roughages, (2) an analysis of relative market prices of alfalfa and prairie hay, and (3) a comparison of market price relationships with relative feeding values.

There are several methods of evaluating the relative feeding value of roughages. The best guide to relative feeding values of roughages is provided by actual feeding experiments with that class of livestock.

A method of comparing roughages is to compute the cost per pound of total digestible nutrients in each feed. This method

is used in comparing the values of feed when protein rich feeds cost no more than those rich in other digestible nutrients.

A variation of this method is to place a definite value on each pound of digestible nutrients and an additional value on each pound of digestible protein. These values are determined from the market price of a protein rich feed as soybean oil meal, and a common grain such as corn.

The use of net energy values is probably more accurate than total digestible nutrients for comparing the relative value of roughages. The net energy values are determined by digestion trials with the animals.

Petersen of the Minnesota station devised a method that can be used to evaluate the relative values of feed even when the price of the base feeds change. Petersen computed constants for each feedstuff based on cottonseed meal and corn. By multiplying the price of cottonseed meal and corn by the constants for the feed, and adding the two products, a figure is secured that gives the value of the feed.

Morrison's feed evaluation factors also use constants for evaluating feedstuffs. This method is similar to Petersen's method. Morrison uses digestible protein and the estimated net energy values in computing his constants; whereas, Petersen used total digestible nutrients and digestible protein.

None of these methods take into account all the factors that determine the value of any feed for a particular class of livestock. The only way that this can be done is through well

planned experiments under practical conditions with that class of livestock.

There is not a complete agreement as to the relative feeding values of roughages. Because of the great variability in roughages it is difficult to say that the relative feeding value is a certain percent of another.

Price analysis is limited to alfalfa and prairie hay because these are the only roughages on which price data is available.

Price ratios for alfalfa vs prairie hay were calculated for a 35-year period. Calculations were made for each five-year period to show how price relationships changed during the period.

Another test of the market price relationships was made (Fig. 3) by comparing the price spreads during the 35-year period.

If the data are plotted on a straight line it indicates that on the average as the market price of prairie hay changes by $1.00 a ton, alfalfa hay will change $1.29 a ton in the same direction.

There has and continues to be a wide fluctuation in price ratios of alfalfa hay and prairie hay. For example, in the 1920-24 period the mean ratio indicates that the price of prairie hay is 70 percent of alfalfa hay while in the 1925-29 period the price of prairie hay is only 60 percent of alfalfa.

Seasonal price movements refer to the ups and downs that regularly occur during certain seasons of the year.

The index of seasonal variation for alfalfa hay shows that there is a strong tendency for alfalfa prices to be low in June and July with the high in January. The index of irregularity indicates that the indicated seasonal trend is fairly reliable.

The index of seasonal variation for prairie hay indicates that prices will be low in July and high in January. The index of irregularity for priaire hay is relatively small and can be used for forecasting future prices.